Moldex objects to this Interrogatory to the extent that it does not state with reasonable particularity the information requested.

Moldex objects to this Interrogatory to the extent that it is overly broad, unduly burdensome, oppressive, redundant, vague and/or ambiguous, including as to time, and especially with respect to the term "circumstances."

Subject to the foregoing specific objections and Moldex's General Objections, Objections to Definitions, and Objections to Instructions, which are incorporated herein by reference, and without waiving these objections and the grounds therefore, Moldex responds as follows:

All of Moldex's sales of the BattlePlugs have been to the U.S. government. The BattlePlugs were originally approved for sale to the military on March 8, 2011, and a corded optional version of the BattlePlug was approved on December 2011. The approval included a recommendation to "initiate the process to bring the Moldex combat earplugs into the Army inventory for issue throughout the Army."

Moldex has sold the earplugs through Owens and Minor, an approved distributor to the U.S. military. Moldex's first orders were from the Program Executive Office (PEO) Soldier who purchased through Owens and Minor after interfacing with Moldex on configuration, packaging, pricing and a shipping schedule. Other orders have been received direct from an Army hospital, the Marines, and one other military entity. All sales to date have been under individual contracts.

INTERROGATORY NO. 8:

Describe in detail all facts and circumstances pertaining to Moldex's assertion in its Answer (Doc. 13) that "Moldex is currently under a contract to provide certain of the accused products in large quantities to the United States military for use by thousands of military personnel . . . ."

RESPONSE TO INTERROGATORY NO. 8:

Moldex objects to this Interrogatory to the extent that it seeks information that is protected from disclosure by the attorney-client privilege and/or the work product doctrine or that is otherwise privileged or protected from or against discovery.

Moldex objects to this Interrogatory to the extent that it seeks information not relevant to any claim or defense asserted in this proceeding, is not reasonably calculated to lead to the discovery of admissible evidence, or is otherwise beyond the scope of permissible discovery in this proceeding, especially to the extent it attempts to shift the burden of proof to Moldex.

Moldex objects to this Interrogatory to the extent that it does not state with reasonable particularity the information requested.

Moldex objects to this Interrogatory to the extent that it is overly broad, unduly burdensome, oppressive, redundant, vague and/or ambiguous, including as to time, and especially with respect to the terms "

Subject to the foregoing specific objections and Moldex's General Objections, Objections to Definitions, and Objections to Instructions, which are incorporated herein by reference, and without waiving these objections and the grounds therefore, Moldex responds as follows:

See response to Interrogatory No. 7.

INTERROGATORY NO. 9:

Identify all persons who were consulted or who provided information in connection with the preparation of your answers to each of these interrogatories, and, for any such person, state the interrogatory or interrogatories in connection with which he or she provided information or was consulted.

RESPONSE TO INTERROGATORY NO. 9:

Moldex objects to this Interrogatory to the extent that it seeks information that is protected from disclosure by the attorney-client privilege and/or the work product doctrine or that is otherwise privileged or protected from or against discovery.

Moldex objects to this Interrogatory to the extent that it seeks information not relevant to any claim or defense asserted in this proceeding, is not reasonably calculated to lead to the discovery of admissible evidence, or is otherwise beyond the scope of permissible discovery in this proceeding, especially to the extent it attempts to shift the burden of proof to Moldex.

Moldex objects to this Interrogatory to the extent that it does not state with reasonable particularity the information requested.

Moldex objects to this Interrogatory to the extent that it is overly broad, unduly burdensome, oppressive, redundant, vague and/or ambiguous, including as to time, and especially with respect to the terms "consulted," "in connection with" and "information."

DATED: June 18, 2012

Respectfully submitted,

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EXHIBIT J

CASE 0:12-cv-00611-JNE-FLN Document 36-8 Filed 01/18/13 Page 2 of 2

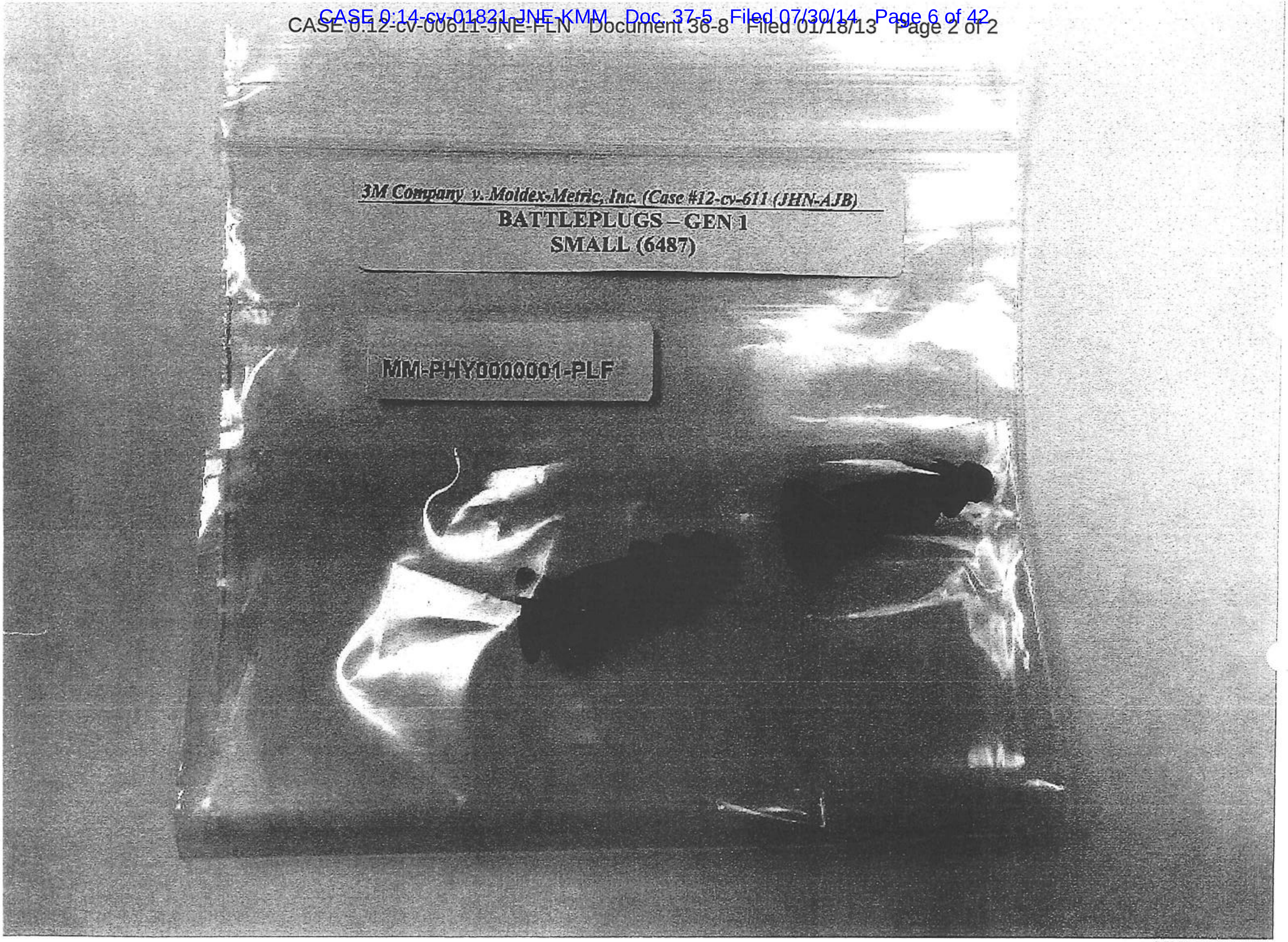

EXHIBIT K


3M Company v. Moldex-Metric, Inc. (Case #12-cv-611 (JHN-AJB)
BATTLEPLUGS – GEN 1
MEDIUM (6488)
MM-PHY00000003-PLF

EXHIBIT L


3M Company v. Moldex-Metric, Inc. (Case #12-cv-611 (JHN-AJB)
BATTLEPLUGS – GEN 1
LARGE (6489)
MM-PHY0000005-PLF

EXHIBIT M

MM00013794

EXHIBIT N

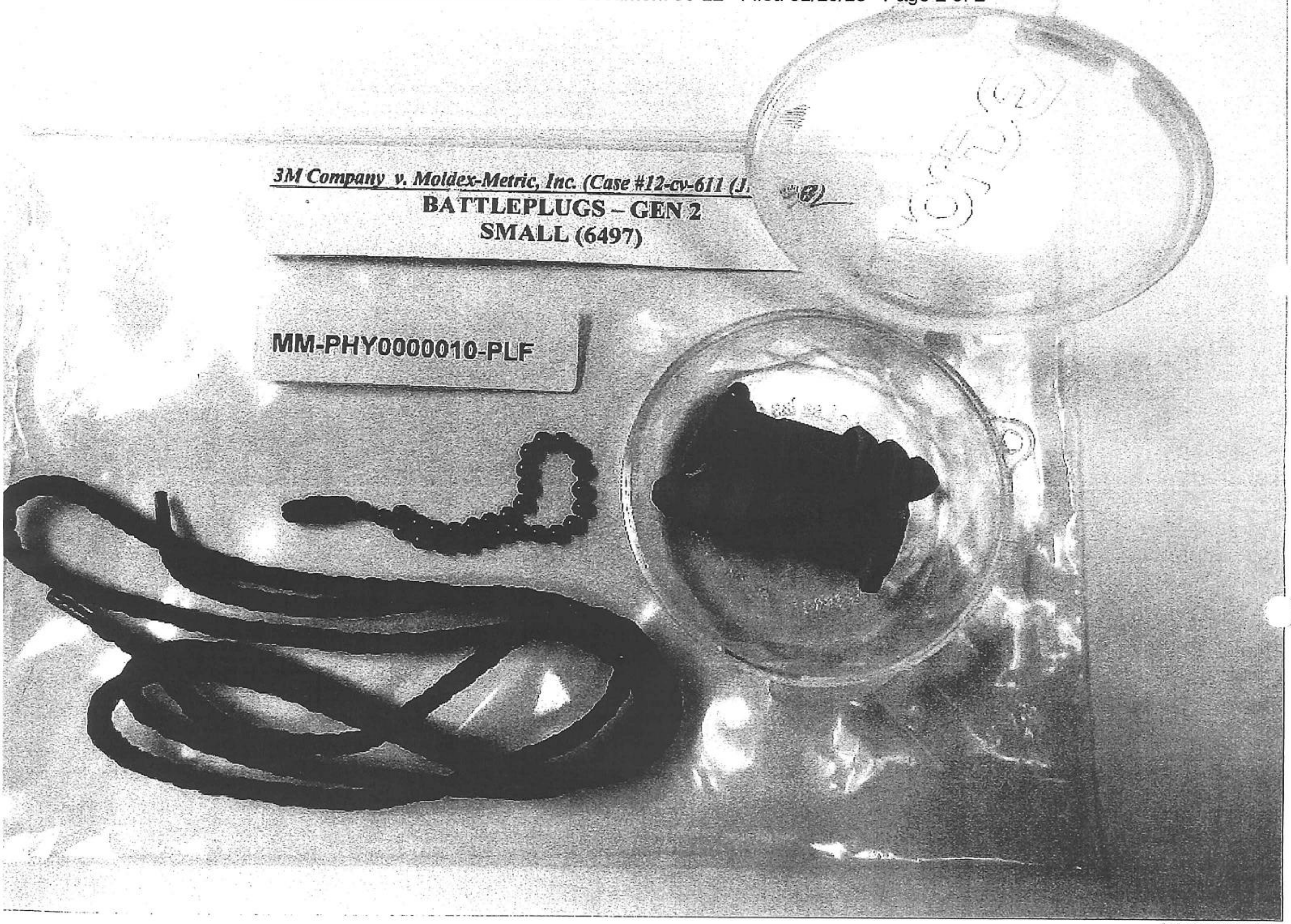
3M Company v. Moldex-Metric, Inc. (Case #12-cv-611 (J.
BATTLEPLUGS – GEN 2
SMALL (6497)
MM-PHY0000010-PLF

EXHIBIT O

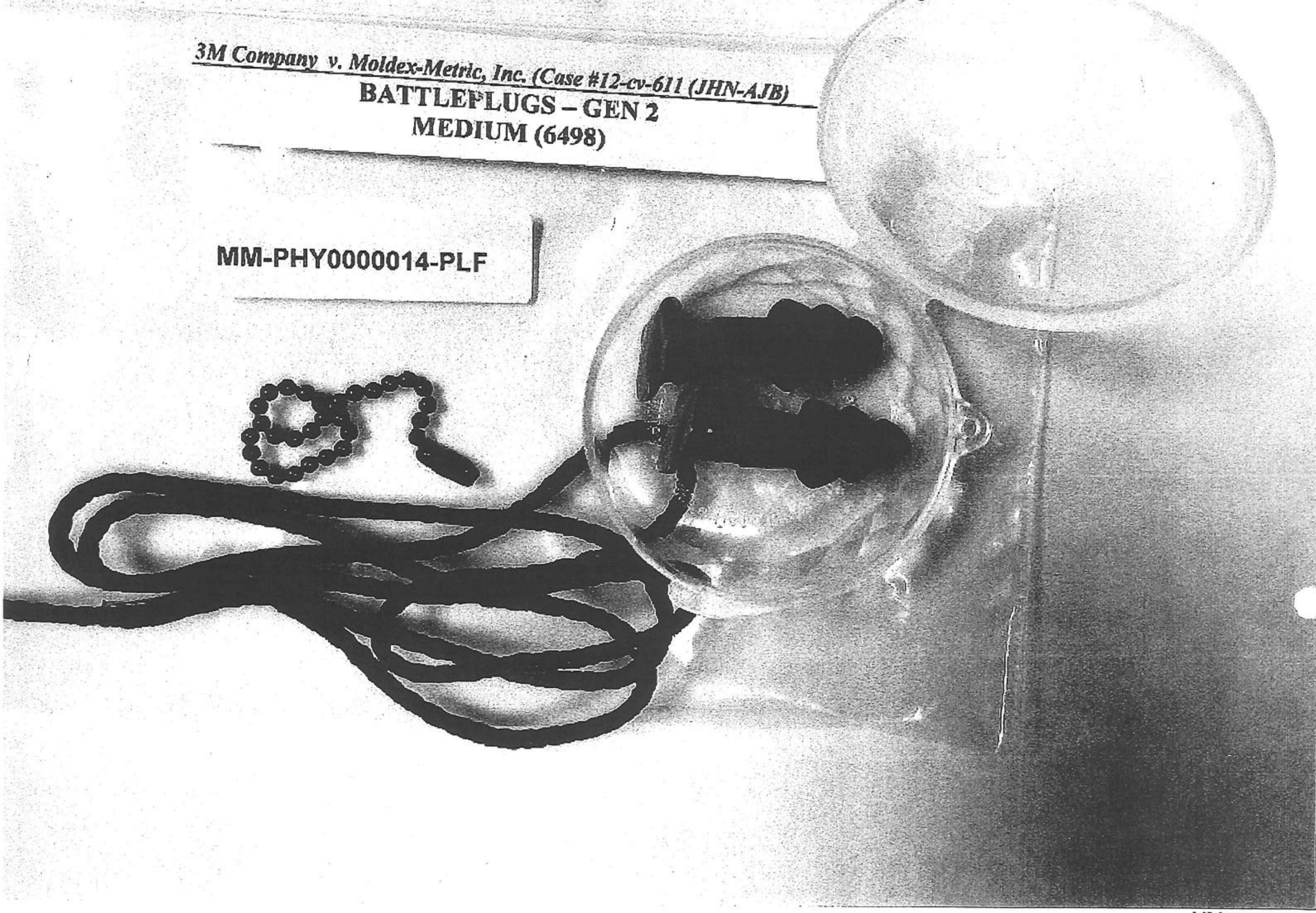
3M Company v. Moldex-Metric, Inc. (Case #12-cv-611 (JHN-AJB)
BATTLEFLUGS – GEN 2
MEDIUM (6498)
MM-PHY0000014-PLF

EXHIBIT P

United States Patent

[11] 3,565,069

[72] Inventor Robert Nelson Miller
745 Teel St., Sparks, Nev. 69220

[21] Appl. No. 809,080
[22] Filed Mar. 21, 1969
[45] Patented Feb. 23, 1971

[54] ACOUSTICAL FILTER DEVICE
4 Claims, 2 Drawing Figs.

[52] U.S. Cl. 128/152
[51] Int. Cl. A61f 11/02
[50] Field of Search 128/152, 153; 2/209; 179/182

[56] References Cited

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FOREIGN PATENTS

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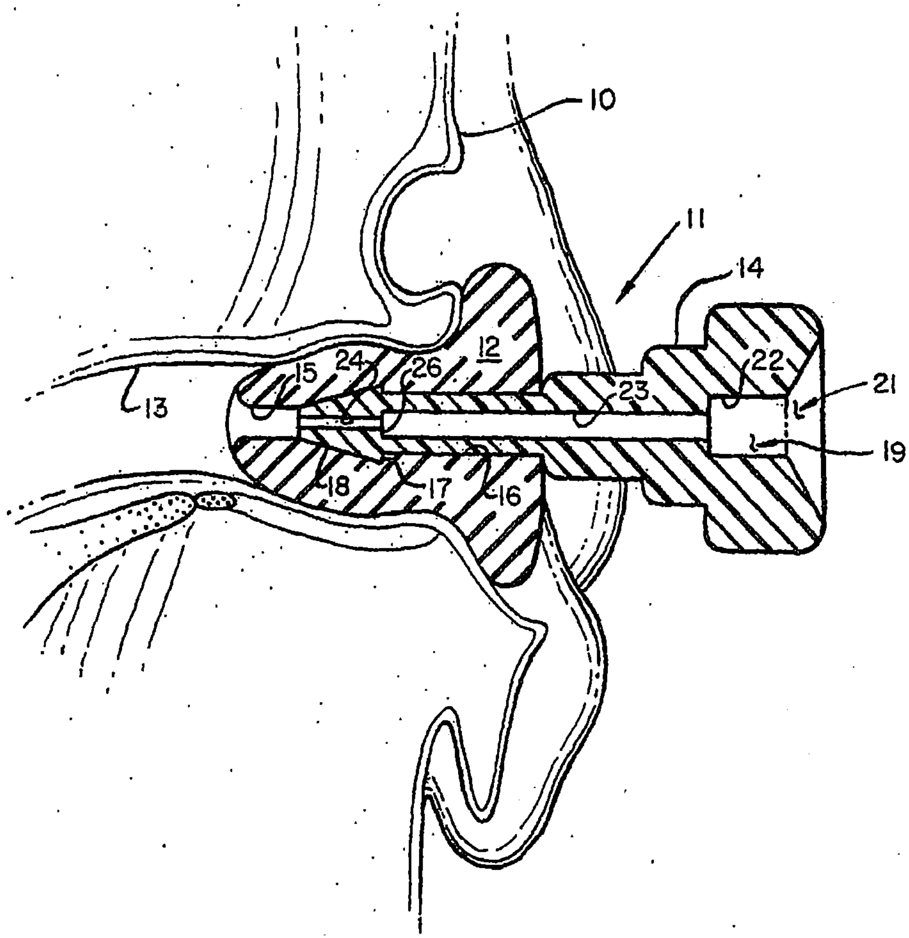
643,927	9/1950	Great Britain	128/152

Primary Examiner—Adele M. Eager
Attorney—Flehr, Hohbach, Test, Albritton & Herbert

ABSTRACT: An acoustical filter device characterized by a filter element serving to screen out substantially all noise about a predetermined level while permitting sound below such level to pass therethrough without deleterious loss. The filter is preferably carried in a support body adapted to be inserted in the outer ear canal of the human ear and to form-fit the respective left-hand and right-hand ear canals. An acoustical filter passage is defined through the support body in open communication with the outside surroundings through which sound is screened out in the above manner.



PATENTED FEB 23 1971 3,565,069

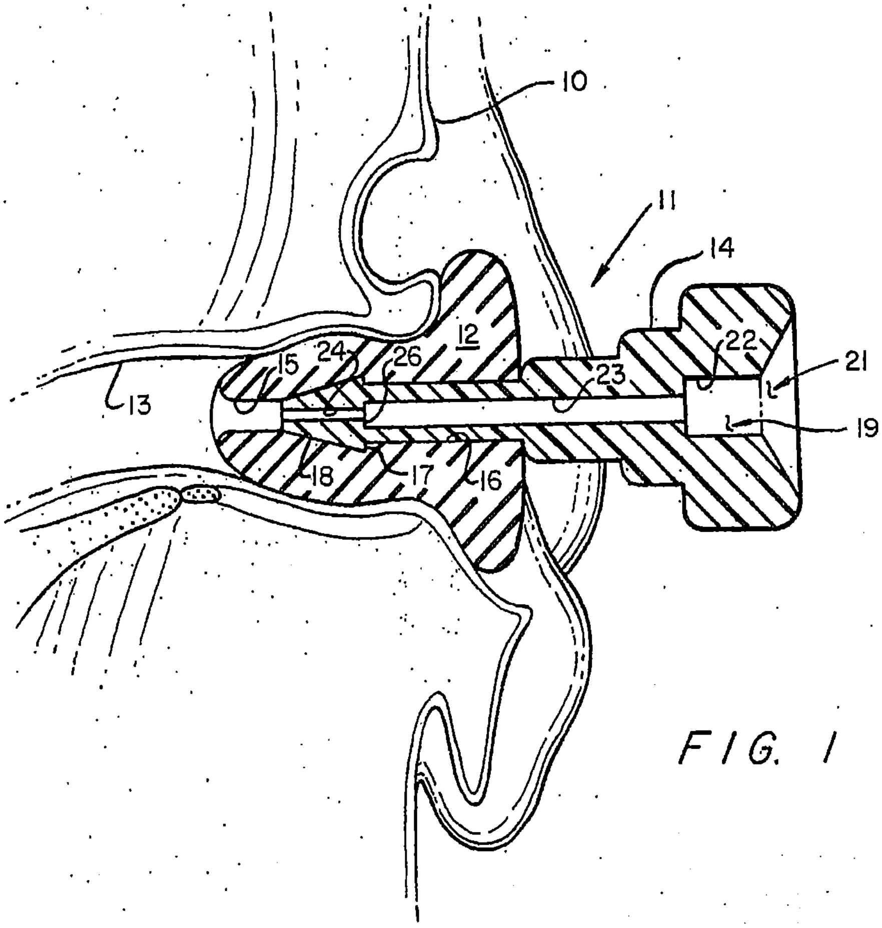


FIG. 1

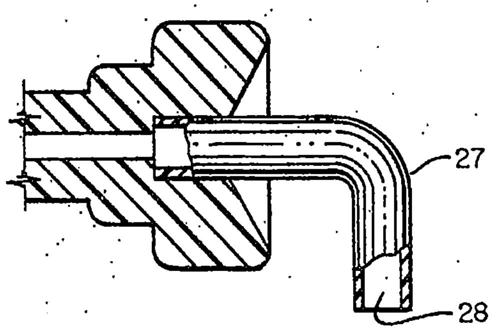


FIG. 2

INVENTOR
DR. R. NELSON MILLER
BY
Fidler, Hohbach, Test, Albritton & Herbert
ATTORNEYS

ACOUSTICAL FILTER DEVICE

BACKGROUND OF THE INVENTION

One way to reduce the level of transmitted sound is to merely provide a complete blockage of the sound path. Thus, to reduce objectionable sound levels to protect the ear, the use of ear plugs has previously been common. Ear plugs have the disadvantage of reducing all sound levels thereby interfering with desired transmissions of sound such as normal speech. Another disadvantage in the use of ear plugs is that they block the inner ear producing imbalance and danger of ear infection caused by the ears being sealed from the atmosphere for extended periods of time.

SUMMARY OF THE INVENTION AND OBJECTS

In general, there is provided an acoustical filter device characterized by a filter element which serves to screen out substantially all noise above a predetermined level while permitting sound below such level to pass therethrough without deleterious loss.

Accordingly, and in a particularly preferred construction, the filter device is carried in a support body adapted to be inserted into the outer ear canal of the human ear. An acoustical filter passage is defined through the support body in open communication with the outside surroundings. The formation of the filter passage serves to restrict the passage of sound above a predetermined level while permitting lower levels of sound to pass therethrough.

In a particularly preferred embodiment, the support body is form-fitted to each of the respective left-hand and right-hand ear canals in a manner whereby all sound entering the inner ear must pass through the filter passage. Thus, the exterior surface of the support body forms an acoustically sealed interface with the ear canal surfaces.

This invention relates to an acoustical filter device which is particularly useful as a filter device adapted to be worn within the outer ear canal.

In general it is an object of this invention to provide an improved acoustical filter device.

It is a further object of this invention to provide an acoustical filter device adapted to be worn within the outer ear canal of the human ear whereby the inner ear is in open communication with the outside surroundings.

It is a further object of the invention to provide an acoustical filter element serving to screen out substantially all noise above a predetermined level while permitting sound below such level to pass therethrough without deleterious loss.

Further objects of the invention will be readily apparent from the following detailed description of preferred embodiments, when considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevation schematic view in section of an acoustical filter device according to the invention.

FIG. 2 is an elevation schematic view of another embodiment according to the invention,

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In providing an acoustical filter to be carried in the outer ear canal 13 of the human ear, such as the ear 10, schematically shown in FIG. 1, an acoustical assembly 11 includes a generally annular elongated support body 12 of suitable resilient, deformable material, such as rubber or polypropylene shaped to conform to the interior surfaces of the outer ear canal.

While being formed in the general nature of an "ear plug" in the sense that it is a body of material which can be carried within the ear, the form of body 12 provides exterior surfaces which conform in a closely fitting relation to the canal sur- [illegible]

or surface of body 12 to enter canal 13. Body 12 includes a filter passage 15 defined therethrough.

Thus, an acoustical filter element 14, lodged centrally of body 12, serves to restrict the passage therethrough of substantially all sound levels above a predetermined level, preferably established at the upper level of human speech. Accordingly, the transmission of noise levels via the filter element 14 is limited to those noise levels falling below a noise level on the order of 80 decibels.

Element 14 engages support body 12 and is held affixed thereto by insertion into an annular bore 16 formed through body 12 to open into canal 13. Element 14 thus includes a conical leading surface portion 18 formed about the inner end thereof and provided with a retaining shoulder 17 at the rear edge of portion 18. The deformable nature of body 12 serves to expand around and behind shoulder 17 whereby withdrawal of element 14 is resisted while insertion of element 14 is aided by the conical surface portion 18.

The exterior portions at the outer end of element 14 are generally concentrically arranged, right cylindrical, portions disposed in steps whereby if it is desired to remove element 14 from body 12, it is possible to manually grip and disengage element 14 from body 12 merely by pulling one from the other against the resistance provided by shoulder 17.

Means for screening out the higher sound levels above a predetermined cutoff level, such as the 80 decibel speech level, is effected by the central passageway defined through element 14 as now to be described.

Thus, the outer end of passageway 19 includes an outer funnel-shaped sound collecting dishlike surface portion 21 which first receives the incoming sound waves.

Immediately inside the region of surface 21, a relatively large cylindrical recess 22 further serves to collect the incoming sounds for travel along passageway 19.

From inspection of the drawing, it will be readily evident that passageway 19 is in open communication between ear canal 13 and the outside surroundings. The incoming sound waves next encounter a somewhat reduced cylindrical resonant chamber 23 which cooperates with a much smaller vent passage 24. At the junction formed at the transition between chamber 23 and vent 24, the end wall surface 26 is abruptly diminished to the restricting diameter of vent 24 whereby incoming sound waves serve to develop an increasing pressure caused by the constriction of the relatively small diameter vent 24 with respect to the relatively large diameter of chamber 23.

The length of chamber 23 is tuned to pass a frequency band on the order of 250 to 4,000 cycles per second as well as the first three harmonics thereof. For example, chamber 23 can be on the order of 3 millimeters in length.

It has been observed that, in order to dissipate and cut off substantially all sound levels above the usual upper level for speech, such as 80 decibels or the like, the ratio of the diameter of chamber 23 with respect to the diameter of vent 24 should run on the order of three to one.

Thus, the foregoing ratio of diameters between chamber 23 and vent 24 serves to screen out noise levels above a predetermined level of noise such as on the order of eighty decibels. This type of device, therefore, is suitable for most industrial usages, such as machine shops and the like, whereby high noise levels can be expected to be experienced.

It has been further observed, that in using the above ratio for the relative diameters, the lower levels of sound pass relatively undiminished through the entire length of passageway 19 whereby a person can hear another party talking clearly, notwithstanding the fact that the listener may be in the immediate presence of noisy operating equipment.

For example, in utilizing the above filter element disposed in support bodies carried in the ears, it has been observed that the sound of a jet engine is reduced to the point where only the low level sound produced by the rush of passing air being discharged from the engine is heard since the remainder of

This can be explained by the observation that noise occurring from any given source can be expected to cover a relatively wide range of levels and that the lower levels are normally not heard or registered by virtue of the fact that they are drowned out by the greater levels of noise. Once the higher noise levels have been eliminated, however, by the filter device **14**, the lower levels will pass through to the listener.

Accordingly, it has been observed that, when wearing the acoustical assembly **11**, the report of a shotgun is minimized whereby only that portion of the sound generated by the firing of the shotgun is transmitted to the listener which lies below the predetermined cutoff level.

Thus, filter element **14** can be arranged to provide a cutoff of all sound above a predetermined level and, if desired, the sound levels below the cutoff level can be reduced by forming vent **24** with a relatively smaller diameter.

Thus, in certain circumstances, such as in the environment of extremely high noise levels as found in and about airports in close proximity to jet engine operation and the like, the above construction may permit the passage of enough higher noise levels, for example, up to a level on the order of 90 or 95 decibels that, if these are objectionable, a reduction in the noise level can be achieved by further increasing the ratio of the diameter of chamber **23** with respect to the diameter of vent **24**. Thus, for use under such circumstances, a ratio on the order of seven to one has been observed to screen out substantially all noise levels above 80 decibels. Under these extreme circumstances some reduction in the transmission of those noise levels below 80 decibels may be experienced which could, for example, require people in conversation to speak somewhat more loudly to be fully heard.

More specifically, an operable filter element and ear assembly **11** have been constructed and operated in accordance with the above wherein chamber **23** has a length of 0.118 inch and a diameter of 0.225 inch, and vent **24** has a length of 0.0787 inch and a diameter of 0.0625 inch.

For high intensity noise levels, such as experienced in the proximity of jet engines and the like, an assembly **11** has been constructed and operated in accordance with the above teaching wherein chamber **23** has a length of 0.118 inch and a diameter of 0.0938 inch, and vent **24** has a length of 0.0787 inch and a diameter of .0135 inch.

Another embodiment, according to the invention, includes the addition of an L-shaped sound transmission tube **27** formed at its inner end with an enlarged exterior diameter for providing a press fit within recess **22** for holding the L-shaped tube **27** in any desired radial orientation.

By utilizing tube **27**, it is possible to partially dissipate all incoming sound by a factor on the order of 10 percent. This can be further improved simply by directing the open outer ends **28** away from the source of the sound.

From the foregoing, it will be readily evident that there has been provided an acoustical filter device whereby a party wearing the filters in each ear can conduct a normal conversation even in the presence of highly objectionable sound.

Further, it will be readily evident that various sizes of support bodies can be made to fit different sizes and shapes of outer ear canals. Thus, a single relatively standard size filter element **14** can be utilized in conjunction with a great number of different support bodies so as to accommodate a wide range of users with a minimum of parts.

I claim:

1. An acoustic device comprising a support body of resilient material shaped and adapted to be inserted into the outer ear canal of the human ear to be worn therein, an acoustic filter passage defined within the body for open communication between the outside surroundings and said ear canal, said acoustic passage being formed to include an open end for collecting and receiving substantially all ambient sound substantially undiminished in energy from the outside surroundings, said filter passage comprising a resonant chamber of predetermined length open to receive substantially all said sound, and a vent of a reduced diameter relative to the diameter of said chamber and forming a junction therewith, said vent leading from said chamber to transmit sound to said canal, the junction between said chamber and vent providing a sufficiently abrupt reduction in said passage and said predetermined length being sufficiently long to cause an increase in pressure in said chamber for sounds above a predetermined level to cause said sounds to become dissipated within said chamber while said vent passes sounds below said level into said canal substantially free of deleterious reduction in the level thereof.

2. An acoustic device according to claim 1 wherein the ratio of the respective diameters of said chamber and vent lies substantially within a range of between seven and three to one.

3. An acoustical filter device comprising a filter element having an open acoustical filter passage therein, said acoustical passage being formed to include an open end for collecting and receiving sound, an L-shaped tube having one end communicating with the source of sound entering said passage, said tube serving to partially dissipate the sound prior to receipt by said filter passage, a resonant chamber of predetermined length open to receive the sound collected, and a vent of reduced diameter relative to the diameter of said chamber, the junction between said chamber and vent providing an abrupt reduction in said passage to cause sounds of a predetermined level to resonate and become dissipated within said chamber while said vent passes sounds below said level.

4. An acoustical filter device to be worn in the ear comprising a form-fitted support body forming an acoustically sealed interface with the ear canal surfaces of the wearer, filter means carried by said body and forming an acoustic passageway in continuously open communication between the ear canal and the outside surrounding, the outer portion of the passageway being formed to define an elongated chamber open at its outer end for receiving all ambient sounds therein at a substantially undiminished energy level and formed at its outer end to include an abruptly diminished vent opening, said acoustic passageway at the junction between said chamber and vent opening being sufficiently abruptly diminished to cause the sound waves entering said chamber to develop an increase in pressure in said chamber and to dissipate energy therein for those sounds above a predetermined level while passing sounds below said level via said vent opening directly into the ear canal of the wearer substantially undiminished relative to those sounds above said level.

EXHIBIT Q

NHCA Feb. 98
Albuquerque

EB → Brian
REK
Armand will present this at NHCA

16,073

NONLINEAR HEARING PROTECTION DEVICES

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ABSTRACT

Passive nonlinear hearing protection devices can provide satisfactory speech intelligiblity, signal detection, and localization and identification of the sound sources in the environment while protecting the ear against large impulses. These devices are especially valuable for the military, as for target and/or hunting shooters. New nonlinear perforated acoustic filters have been developped by the French-German Research Institute of Saint-Louis. These filters (overall length: 3.7 mm, outside diameter: 3.0 mm) can be inserted in a variety of earplugs. The nonlinearity is manifest for impulses and for continuous noises beyond 110 dB peak. It increases with the level of the impulses: the Noise Reduction of the peak pressure increases from 8 dB to 25 dB when the external peak pressure comes from 110 dB to 190 dB. In the low frequency range the Insertion Loss increases by about 30 dB from 110 dB (IL: 0 dB at 300 Hz) to 190 dB peak pressure (IL: 30 dB at 300 Hz). Such earplugs have been demonstrated to fully protect the ear against impulses up to 187 dB peak pressure (100 rounds) by the US Army (Dr. D. Johnson, Albuquerque), when they are well-fitted. Experiments performed on soldiers in the French Army during rifle and mortar shooting have confirmed the efficiency of this new design. The final design of these plugs will also allow to get a full attenuation (if necessary) even at moderate levels in case of exposure to large continuous noises.

INTRODUCTION

The impulse noises produced by weapons are highly hazardous and are frequently the cause of acoustic trauma (NATO, 1987). In the military, hearing impairments and their correlates: tinnitus, difficulties in understanding of speech... represent an important prejudice for the health of the soldiers. This prejudice is considered as a war injury and can be compensated for. In 1995, 251.9 million dollar have been distributed to 59,088 veterans of the US forces who had hearing loss as a primary disability (an additional 200,975 veterans had hearing loss as a secondary disability) (Ohlin, 1995). In 1996 in France, 966 soldiers suffering from acute acoustic trauma have been treated in the military hospitals (medical expenses: 4 million dollar). The yearly cost of the compensations to the French veterans is about 60 million dollar (CCSA, 1997).

Therefore, the use of well-fitted and very effective Hearing Protectors (HP) is absolutely necessary during shooting exercises. However, wearing HP deteriorates the performance of the soldier: discomfort, difficulties to detect, identify and localize acoustic sources, difficulties to understand speech and intercom systems (Price, Kalb, and Garinther, 1989) (Peters and Garinther, 1990).

If the security and/or the operational abilities of the soldier are impeded, the risk is that the HP will be poorly fitted, not to say left off. As a single impulse noise is often able to produce final hearing damages, designing a HP for military use must take into account as well the protection as the operational angles of the problem.

To protect the ear against impulse noises without impairing the military efficiency, the passive nonlinear Hps, of which the attenuation increases with the level of the stimulus, are an attractive solution. They are cheap, easy to maintain, they work without power supply and without intervention of the subject, and are readily compatible with other head equipments. As they present little Insertion Loss (IL) at low levels (especially at low frequencies), the nonlinear HPs allow speech communication, and detection and localization of acoustic sources in about the same conditions as without protection. All the same, they afford a protection adapted to occasional exposures to impulse noises such as those produced during training or combat (Dancer, A., Grateau, P., Cabanis, A., Barnabé, G., Cagnin, G., Vaillant, T., and Lafont, D., 1992). We shall study the performance of some existing nonlinear HPs and present the results obtained with new nonlinear earplugs.

ATTENUATION MEASUREMENTS

To assess the attenuation afforded by earplugs and earmuffs at very high-level impulse noises, the classical measurements performed by means of the subjective method (Real-Ear-At-Threshold - REAT - ISO 4869-1, 1990) are not suitable (Berger, 1986). First of all, this method does not allow to evaluate the peak pressure of an impulse noise under a HP. Even if serious doubts exist about the pertinency of "peak level" measurements under a HP as part of the classical Damage Risk Criteria (DRC) (Dancer, 1992) (Johnson and Patterson, 1992) (Patterson, Mozo, and Johnson, 1993) (Patterson, and Johnson, 1996), it is nevertheless essential to get this information. Moreover, the apparition of a nonlinearity, its importance, its characteristics as a function of the pressure-time history of the impulses as well as its net effect, are generally unpredictable. The same kind of limitations apply to the "Microphone-In-Real-Ear" (MIRE) measurement technique (Hellström, 1992). In practice, peak level and pressure-time history of the impulses cannot be easily and directly measured close to the tympanum by MIRE. Moreover, this technique is unsuitable for earplugs attenuation measurements and MIRE is impossible to use as a routine technique with high-intensity impulses because of the security of the subjects.

Therefore, the only possibility to assess the nonlinear behaviour of the HPs, when exposed to impulse noise (up to 190 dB SPL), is to use an Artificial-Test-Fixture (ATF) and preferably an artificial head with an ear simulator (Dancer, Franke, Parmentier, and Buck, 1996).

Artificial Test Fixtures

ATFs are currently used to measure the physical attenuation afforded by earmuffs in steady-state noise. In these conditions the ATFs must comply with standards (ISO, 1989 and/or ANSI, 1974) (fig. 1). As the commercially available ATFs (artificial head B&K type 4128 equipped with the ear simulator type 4157, Knowles Electronics Manikin for Acoustic Research - KEMAR - equipped with the Zwislocki's ear simulator, HEAD Acoustics GmbH equipped with the B&K ear simulator) provide insufficient acoustic insulation (fig. 1), we designed a new ATF in order to obtain better performance. The ISL "head" was made of polyurethane and was arranged to fit: (i) the HEAD Acoustics device corresponding to the external ear and the circumaural

region, (ii) the B&K ear simulator (equipped with a 1/4" microphone type 4136). The measured Transfer Function of the Open Ear (TFOE) of the ISL ATF is in close agreement with the experimental data published by Shaw (1974) and is linear up to a peak pressure of about 190 dB at the ear microphone.

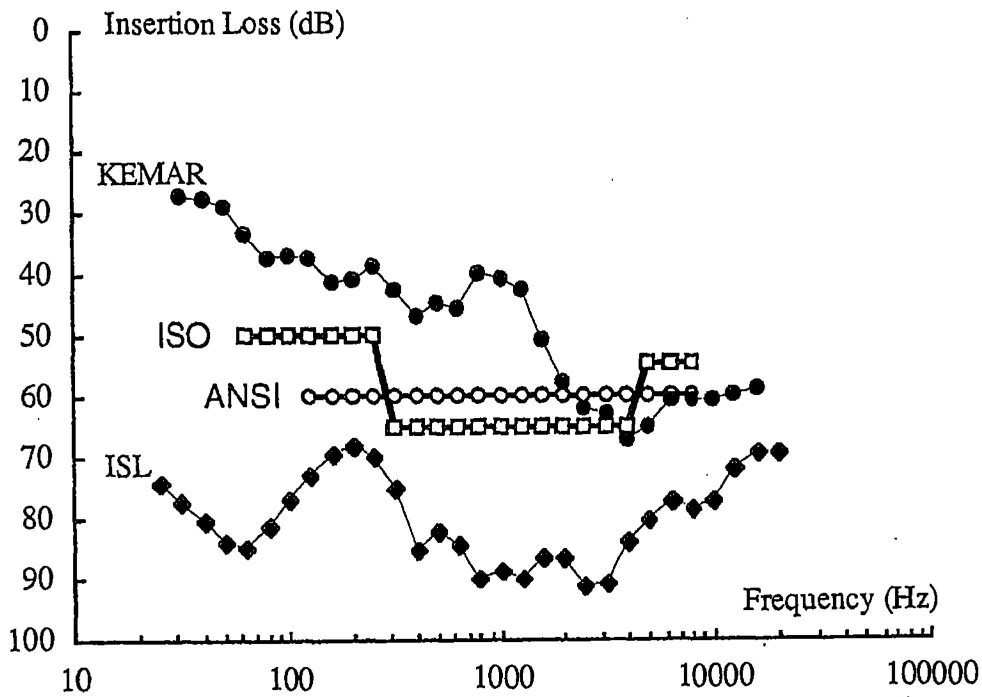

FIGURE 1

Minimal Insertion Loss of ATF as defined by the ISO and ANSI standards.
Insertion loss performance of the KEMAR and ISL ATFs (1/3 oct. bands)

When the ISL ATF "earcanal" is sealed, the maximum IL undergoing the exposure to Friedlander waves (i.e., shock waves in free field) is better than 80 dB from 0.4 to 5 kHz, and well better the ANSI and ISO criteria (fig. 1). It is now possible to study the nonlinear behaviour of earmuffs and earplugs without any limitation of the dynamics of the measurements.

INSERTION LOSS OF NONLINEAR HEARING PROTECTORS IN HIGH-LEVEL IMPULSE NOISE

E.A.R. Ultra 9000 Earmuff

This passive muff is designed to be nonlinear and to present larger attenuation values when the noise level increases beyond 110 dB.

Figure 2 presents the IL of this muff as a function of frequency (1/3 octave bands) for impulses of 110, 130,150 and 170 dB peak pressure (A-duration: 2 ms, normal incidence). Beyond 130 dB, a favourable nonlinearity is observed from 0.5 to 10 kHz (in this frequency range IL increases by 10 to 14 dB when the level of the impulse goes up from 130 to 170 dB).

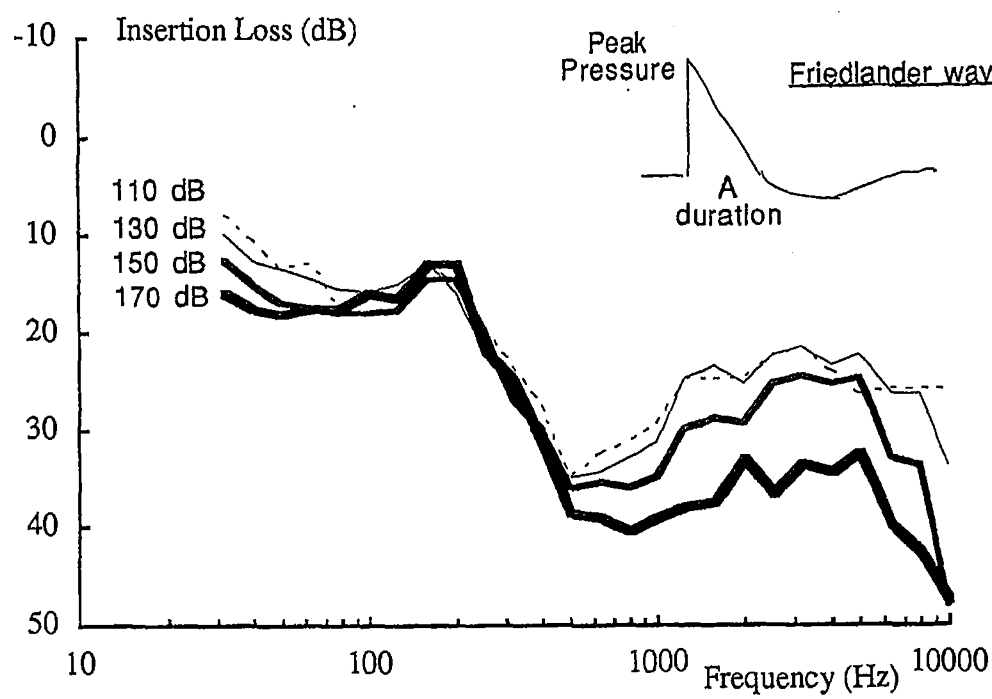

FIGURE 2

Insertion Loss afforded by the E.A.R. 9000 earmuff for different levels of the impulses (measured with the ISL ATF)

RACAL Gunfender Earplug

The RACAL Gunfender earplug is made nonlinear by means of a metallic plate (0.15 mm in thickness) which is inserted inside the earplug perpendicular to its axis and perforated in its center by a hole (0.5 mm in diameter). The acoustic resistance through the orifice increases with the peak level (Sivian, 1935) (Ingard, and Ising, 1967) (Hamery, Dancer, and Evrard, 1997). This earplug has been proven to act as a nonlinear mechanism allowing the attenuation to increase with the stimulation level beyond 120 to 140 dB (Forrest, and Coles, 1970) (Shaw, 1982). Figure 3 presents the IL of the RACAL Gunfender earplug as a function of frequency for impulses of 110, 130, 150, 170 and 190 dB peak (2 ms A-duration). The attenuation of the peak pressure from free field to the microphone of the artificial ear (Noise Reduction of the peak pressure: NR peak) is also shown on this figure. The nonlinearity is the largest at medium frequencies (0.5 to 2 kHz). Beyond 150 dB, the IL increases by about 0.4 dB/dB around 1 kHz. The NR peak increases by about 10 dB from 130 to 190 dB. Because of the influence of the TFOE, at the lowest levels the NR peak is negative and corresponds to an amplification of the peak pressure.

Although this plug was demonstrated to protect the ear during unfrequent exposures to weapon noises (rifle, antitank weapon, howitzer) (Dancer et al., 1992), its nonlinear performances were considered much too limited to be chosen as a regular HP by the French Army. Moreover, the RACAL Gunfender suffers many inconveniences: it is difficult to fit (a perfect sealing is essential for a nonlinear earplug to work properly)

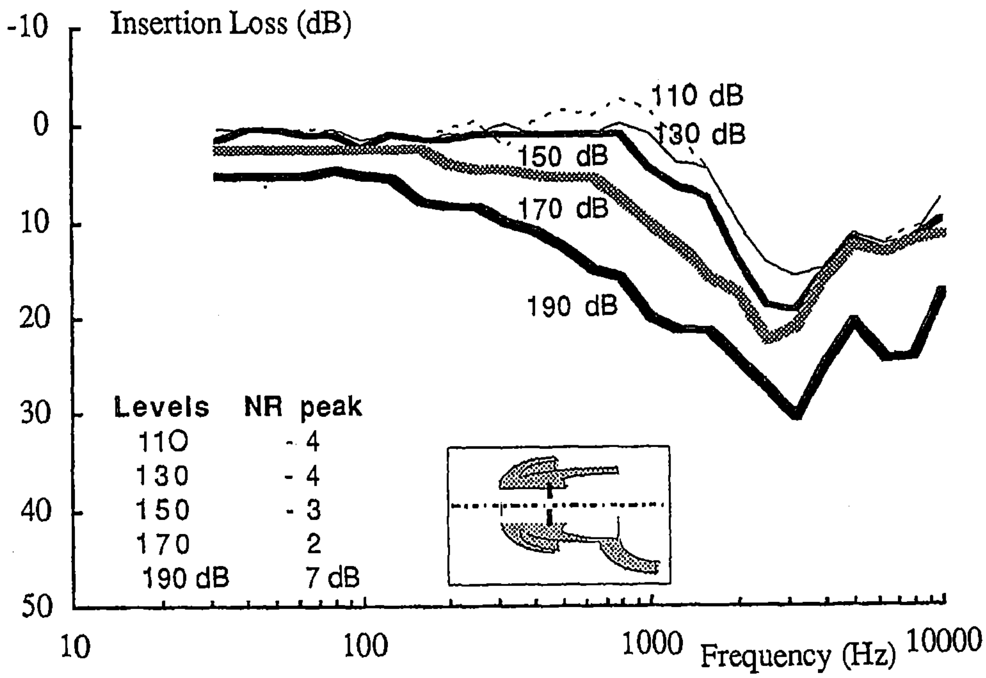

FIGURE 3
Insertion Loss and NR peak afforded by the RACAL Gunfender earplug for different levels of the impulses (measured with the ISL ATF) (1/3 oct. bands).

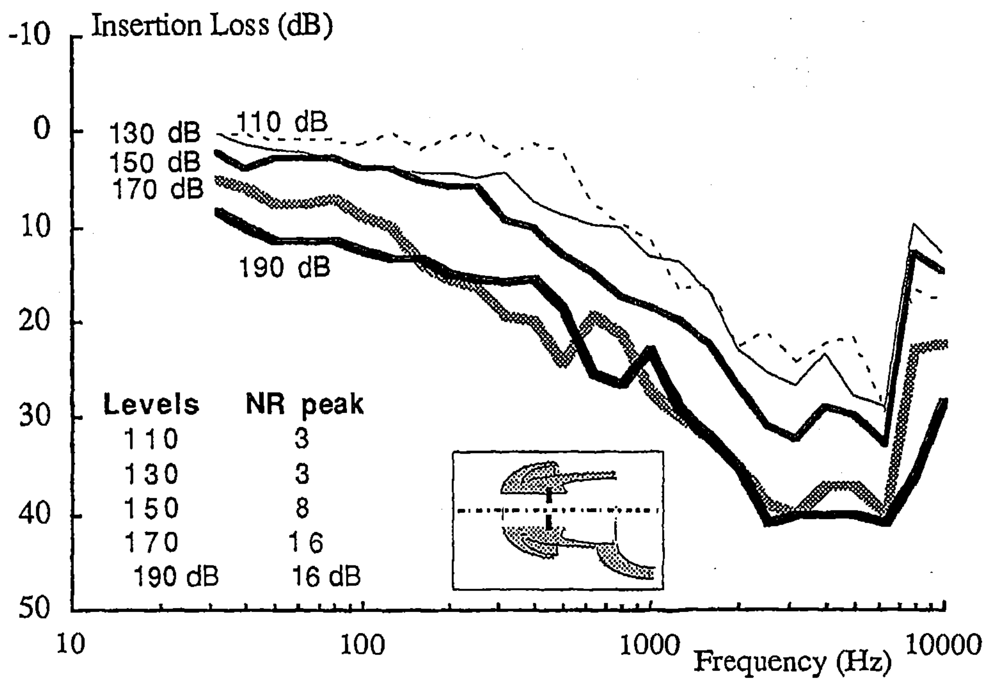

FIGURE 4
Insertion Loss and NR peak afforded by the "improved" RACAL Gunfender earplug for different levels of the impulses (measured with the ISL ATF) (1/3 oct. bands).

CASE 0:12-cv-006__-JNE-FLN Document 36-15 Filed _/18/13 Page 7 of 11

and very uncomfortable (permanent use is impossible). Therefore, we decided to look for a new nonlinear earplug design with better performance and better ergonomics.

"Improved" RACAL Gunfender Earplug

Given the original RACAL Gunfender earplug, we modified the dimensions of the metallic plate (the nonlinear component) and measured the corresponding changes in Insertion Loss. Systematic variations in thickness of the plate, in diameter, shape and position of the hole, in the number of holes... led us to an optimized configuration. The best nonlinear characteristics were obtained with a plate of 0.10 mm in thickness and one hole of 0.30 mm in diameter. Figure 4 presents the IL as a function of frequency for impulses of 110, 130, 150, 170 and 190 dB peak (A-duration: 2 ms). The frequency range over which the nonlinearity is significant is wider than with the original RACAL Gunfender earplug (0.05 to 6 kHz). Moreover, the nonlinearity begins at lower levels (130 dB) and reaches its maximum at 170 dB instead of 190 dB. The NR peak increases by 13 dB from 130 to 170 dB.

ISL "filter"

As it seemed impossible to get better performances with a single plate arrangement, we decided to study the characteristics of small cylindrical cavities terminated by two perforated plates. Extensive measurements allowed to determine the influence of the dimensions of the cavity, the thickness of the plates, the diameter of the holes..., on the nonlinear performance.

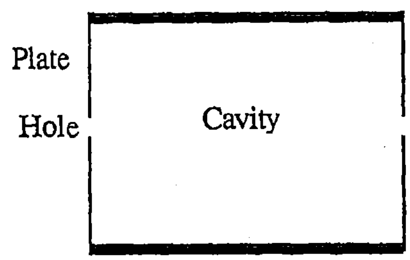

FIGURE 5

Schematic representation of the ISL "filter" (overall length: 3.7 mm, outside diameter: 3.0 mm, inside diameter: 2.0 mm). The thickness of the perforated plates is 0.10 mm and the diameter of the holes is 0.30 mm.

The "filter" which is represented in figure 5 corresponds to the best dimension/ performance compromise. In its final version it is made by plastic injection moulding (in two parts). As it is necessary to get precise and reproducible dimensions of the plates and of the holes as well as sharp edges and even surfaces to ensure good and uniform performances, the factory limits must be very strict.

The outside dimensions of this filter allow its insertion in a classical earplug which has been chosen for its ergonomics: easiness to fit, good sealing, comfort. In our study, we used a modified E.A.R. Ultrafit (with a sound passage - a small tube - between the two ends of the earplug).

Nonlinear ISL-EAR Ultrafit Earplug

Figure 6 presents the IL of the nonlinear ISL-EAR Ultrafit earplug as a function of frequency for impulses of 110, 130, 150, 170 and 190 dB peak (A-duration: 2 ms). We can note the increased nonlinear performances compared to the original and "improved" RACAL Gunfender earplugs (see fig. 3 and 4). The frequency range for which the nonlinearity is significant goes from 0.025 to 10 kHz. The nonlinearity begins at 110 dB and increases by about 0.4 dB/dB around 0.3 kHz. The NR peak increases by 17 dB from 110 to 190 dB.

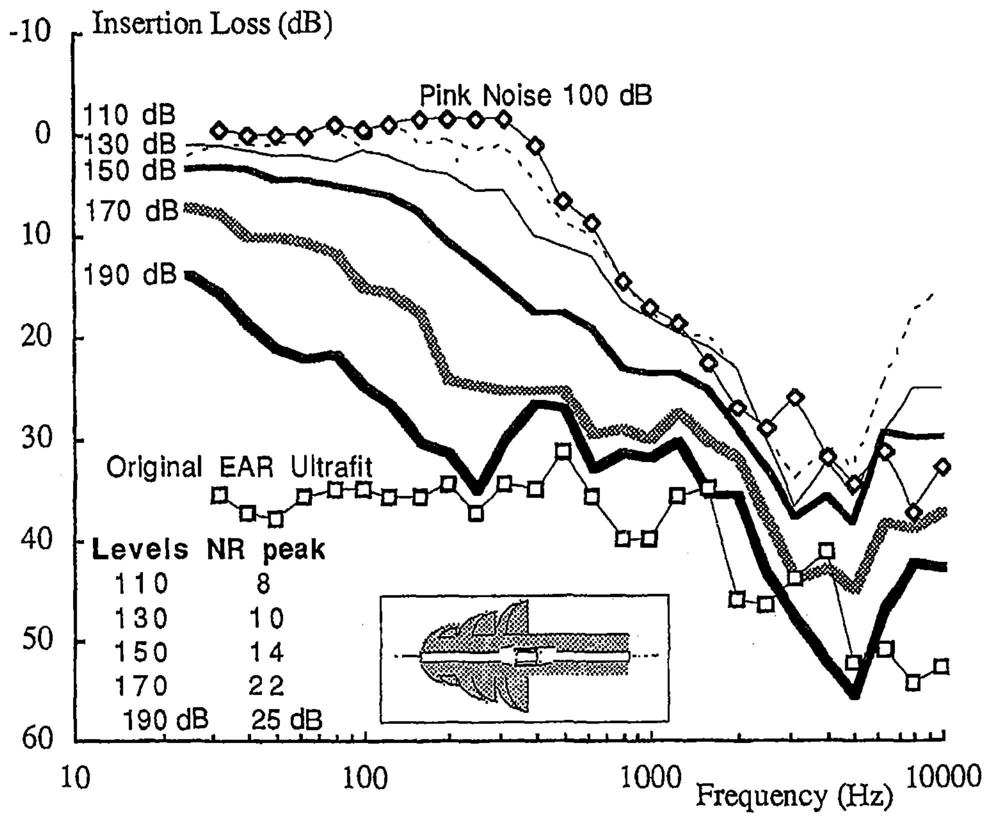

FIGURE 6

Insertion Loss and NR peak afforded by the ISL-EAR Ultrafit earplug for different levels of the impulses (1/3 oct. bands). Insertion Loss afforded by the ISL-EAR Ultrafit earplug when measured with a pink noise at 100 dB (full line and diamonds). Insertion Loss afforded by the original EAR Ultrafit earplug when measured with a pink noise at 120 dB (full line and squares).
All measurements are performed with the help of the ISL ATF.

It is interesting to note that at low levels, the IL of the nonlinear ISL-EAR Ultrafit earplug is small (therefore allowing speech communication and detection and localization of environmental noises), whereas at the highest levels the amount of protection (IL) is quite comparable (beyond 0.2 kHz) to the original (linear) EAR Ultrafit earplug.

FIELD TESTING OF THE ISL-EAR ULTRAFIT NONLINEAR EARPLUG

Speech Intelligibility, Sound Detection And Localization

Thanks to a model developped at the HRED (G. Garinther and J. Kalb, Aberdeen Proving Ground, MD) it has been possible to evaluate the distance at which different noises (vehicle noise, steps in leaves, closing of a bolt...) can be detected with the nonlinear earplug. For example, in low suburban environmental noise, a truck can be detected at the same distance (800 m) either with or without the nonlinear plug whereas the detection distance is halved when the subject is equipped with a (linear) foam plug. In the same conditions closing a bolt can be heard at 900 meters without HP, at 500 m with the nonlinear plug, and at 60 meters only with a (linear) foam plug. Validation of the results obtained with this model has been performed on the shooting range during an exercise: the soldiers remain aware of their acoustic environment.

On the other hand, CVC tests and direct evaluation of the speech intelligibility on the field have demonstrated the interest of this design for the military. Soldiers can communicate without shouting (as it is the case when they use linear foam earplugs for example).

Hearing Protection Against Impulses

The actual efficiency of the nonlinear ISL-EAR Ultrafit earplug has been assessed by Johnson (Johnson, and Dancer, 1997). 14 soldiers have been exposed to Friedlander waves ($6 \leq n \leq 100$) with peak pressures going from 174 dB to 193 dB (A - duration: 1.5 ms) at 1 minute interval. When the plug was perfectly fitted into the earcanal, in all but one subject no significant TTS (TTS $\leq$ 15 dB from 0.125 to 8 kHz) was observed after the exposure (5 minutes, 20 minutes and 1 hour) to 6 impulses of 190 dB. In France, soldiers have been exposed to rifle noise (160 dB peak, A-duration: 0.25 ms, 30 rounds) and mortar noise (183 dB peak, A-duration: 3 ms, 7 rounds). No significant TTS was observed either 5 minutes or 1 hour after the exposures.

From these NIHL studies we conclude that it is actually possible to protect the ear against high- and very high-level impulse noise exposures with the help of the nonlinear ISL-EAR Ultrafit earplug.

CONCLUSION

The new nonlinear earplug design (of which the nonlinearity begins at about 110 dB) afford a protection adapted to occasional exposure to impulse noise such as those produced during training or combat. Unlike classical (linear) earplugs and due to a limited insertion loss for low and moderate levels (especially at low frequencies), they allow speech communication, and detection and localization of acoustic sources in about the same conditions as an unprotected subject, thus avoiding problems of overprotection. The final design of these plugs will also allow to get a full attenuation even at moderate levels in the case of exposure to continuous noise (by manually plugging the sound passage between the two ends).

These new earplugs, which represent a good compromise between the so far opposed requirements: hearing protection and operational capabilities, will be used by the French infantrymen in the near future.

ACKNOWLEDGMENTS

The authors would like to thank A.E.A.R.O. (Indianapolis, USA) and P.R.O.T.A.C. (Le Petit Quevilly, France) for providing various equipments, and Dr. Elliott Berger who was very helpful during this study.
This work was supported by Research Grant 93 02 155 from the Etablissement Technique de Bourges (DGA).

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EXHIBIT R

Sept. 13, 1955 J. S. KNIGHT 2,717,596

CUSHION MOUNTING FOR MASS IMPEDANCE RESONANCE FILTER

Filed April 26, 1954

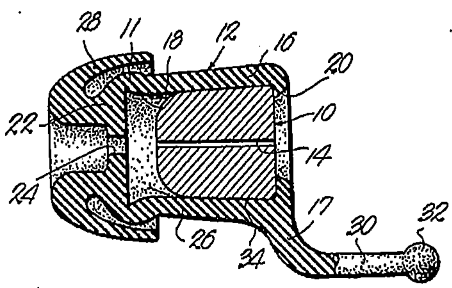

Fig. 2.

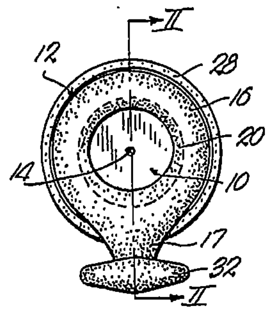

Fig. 1.

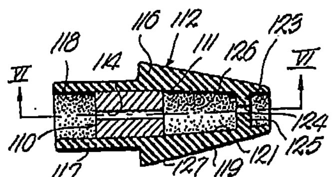

Fig. 5.

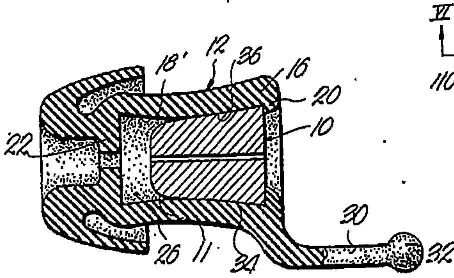

Fig. 3.

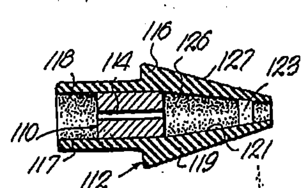

Fig. 6.

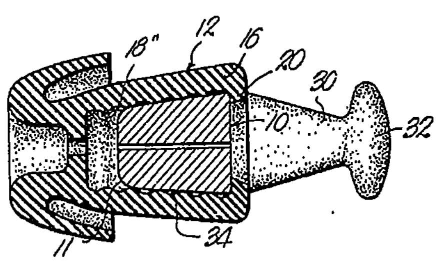

Fig. 4.

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ATTORNEY.

United States Patent O ce

2,717,596
Patented Sept. 13, 1955

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2,717,596

CUSHION MOUNTING FOR MASS IMPEDANCE RESONANCE FILTER

John S. Knight, Kansas City, Mo.

Application April 26, 1954, Serial No. 425,456
6 Claims. (Cl. 128—152)

This invention pertains to hearing guards for preventing damage to the inner ear and contiguous brain sections due to blast, shock waves or excessive sound levels. More particularly, this invention relates to improvements over the hearing guard and ear protector illustrated in Fig. 1 of U. S. Letters Patent No. 2,427,664 issued September 23, 1947, of which I am a co-inventor.

Although the broad, general principles utilized in the hearing guard of Fig. 1 of the above-mentioned patent have proven sound in every respect, and the structure therein disclosed has been used to great advantage, it has been discovered that, by certain structural changes of relatively small significance from the standpoint of manufacturing costs, significant improvements in operating results and versatility can be obtained.

Accordingly, it is the primary object of this invention to provide improved cushion mounting structure for mass impedance resonance filters, which makes possible new and improved results not attainable with any known prior construction.

It is another of the most important objects of this invention to provide mounting structure for a generally frusto-conical, heavy mass impedance plug which will prevent shifting of the plug to one side or the other within the mounting and which will, in addition, utilize frictional engagement between the side walls of the mounting chamber and a substantial portion of the side wall of the plug, as well as the inertia of the plug itself, to retard movement of the plug along its axis under the force of external blasts, shock waves and other influences.

Another important object of this invention is to provide improved tab means for use in emplacing and removing the hearing guard from the outer canal of a human ear, which means does not interfere with external parts of the ear and is always disposed for ready access in quickly seating in and removing the hearing guard from the ear.

Still other objects of the invention will be made clear or become apparent as the following specification progresses. Reference is made to the accompanying drawing, wherein:

Figure 1 is an end elevational view of one type of ear protector made in accordance with this invention;

Fig. 2 is a cross sectional view of the form of the invention shown in Figure 1 taken on line II—II of Figure 1;

Fig. 3 is a cross sectional view similar to that of Fig. 2, but showing a modified form of the invention;

Fig. 4 is a cross sectional view similar to that of Fig. 2, but showing still another modified form of the invention;

Fig. 5 is a cross sectional view of another type of ear protector made in accordance with this invention; and

Fig. 6 is a cross sectional view of the form of the invention shown in Fig. 5, taken on line VI—VI of Fig. 5.

The structure by which the improved ear protectors of this invention illustrated in Figs. 1 to 4 inclusive provide structure capable of offering sufficient mass impedance to resist sudden pressure changes with a minimum of exposed area, while providing for the hearing of normal conversation in a quiet environment and the equalizing of air pressure in the outer canal of the human ear, includes, most broadly, a heavy mass impedance member or filter plug designated 10 and cushion mounting means for plug 10 designated 12 in the accompanying drawing.

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Plug 10 is preferably formed of lead or other heavy, metallic material and is elongated and substantially frusto-conical in form, having its smaller end slightly rounded as at 11. Plug 10 has an elongated, axial bore 14 extending longitudinally therethrough to permit the passage of sound waves of frequencies encountered in normal conversation, a bore diameter of approximately .03 inch in a filter plug of approximately .25 inch in length and weighing in the neighborhood of .005 pound having been found satisfactory.

Mounting 12 is preferably formed of rubber or other resilient material and includes an elongated casing portion 16 having an internal, side wall surface 18 of annular, transverse cross section, an inturned annular flange 20 on one end of casing 16, and a circular disc 22 having a central perforation 24 therein on the opposite end of the casing 16, thereby presenting a chamber 26 within casing 16 for receiving plug 10 between flange 20 and disc 22. Annular flange structure 28 is provided on the end of casing 16 adjacent disc 22 for engaging the walls of the outer canal of a human ear and holding mounting 12 in sealed condition therein. Casing 16 includes a flared portion 17 extending substantially radially therefrom adjacent the end of casing 16 carrying flange 20. An elongated, tapered tab 30 having an elongated knob 32 on the free end thereof extends longitudinally of casing 16 from the flared portion 17 thereof to provide, in conjunction with portion 17, means which will remain extended from the canal of the ear when mounting 12 is emplaced therein for use in emplacing and removing mounting 12 from the ear.

In the form of the invention particularly illustrated in Fig. 2 of the drawing, the inner surface 18 of casing 16 is longitudinally straight throughout a major portion of its length and is tapered to give chamber 26 a decreasing diameter as the end of casing 16 adjacent flange 20 is receded from. It is also significant that the diameter of chamber 26 adjacent flange 20 is substantially the same as the diameter of plug 10 at its larger end and that the taper of side wall surface 18 as flange 20 is receded from is substantially the same as the taper of the frusto-conical surface 34 of plug 10. Accordingly, a substantial portion of surface 34 of plug 10 is in frictional engagement with the interior surface 18 of casing wall 16 so that movement of plug 10 toward disc 22 under the influence of external forces impinging thereon from the end of casing 16 carrying flange 20 is retarded, not only by the inertia of plug 10, but also by the frictional interengagement between surfaces 18 and 34.

It should also be noted that, due to the fact that the taper of surface 18 is at least as great as the taper of surface 34, the longitudinal axis of plug 10 cannot shift relative to casing 16 and become jammed within chamber 26.

In the form of the invention particularly illustrated in Fig. 3, interior surface 18′ of casing wall 16 is longitudinally convex so that the angle of taper thereof throughout a portion 36 of surface 18′ adjacent flange 20 is greater than the uniform angle of taper of surface 34 of plug 10. This construction serves to further increase the frictional effect between surfaces 18′ and 34, to further aid the inertia of plug 10 itself in retarding the latter against reciprocation toward disc 22 under various influences.

In the form of the invention particularly illustrated in Fig. 4, inner surface 18'' of casing wall 16 is longitudinally undulated along an angle of taper preferably equal to that of surface 34 of plug 10. The latter described undulating surface 18'' serves to even further increase the frictional effect which may be obtained between surfaces 18'' and 34 to aid in retarding movement of plug 10.

It is significant that the particular surface construction 18 or 18' or 18'' best adapted for use under given circumstances will depend upon local conditions and, accordingly, the degree by which it may be desirable to aid the inertia of plug 10 in yieldably resisting external influences.

Referring now to Figs. 5 and 6 wherein is illustrated another embodiment of ear protector made in accordance with the principles of this invention whereby inertia of a filter plug is aided in resisting external forces by frictional engagement between a substantial portion of its lateral surface and the walls of a resilient, tubular casing in which it is housed. The numeral 110 broadly designates an elongated, preferably cylindrical filter plug provided with a longitudinal bore 114 and disposed within an elongated chamber 126 of tubular, cushion mounting structure broadly designated 112 and formed of resilient material. Plug 110 preferably has one end slightly rounded as at 111.

Mounting structure 112 comprises a casing 116 having an outer cylindrical portion 117 and a tapered portion 119, the latter being adapted to fit within the outer portion of a human ear. That part of chamber 126 within cylindrical casing portion 117 is also cylindrical and of substantially the same transverse cross section as plug 110, in order to accommodate the latter therein with a major portion of the lateral surface of plug 110 in frictional engagement with the internal, side wall surface 118 of casing portion 117. That part 121 of chamber 126 disposed within tapered casing portion 119 is also inwardly tapered as portion 117 is receded from. It will be clear that the tapering of internal casing surface 121 will tend to resist travel of plug 110 in a direction as to the right in Figs. 5 and 6 when plug 110 is advanced by external forces to that part of chamber 126 disposed within tapered casing portion 119. Such action obviously aids the inertia of plug 110 itself and the frictional engagement between the lateral surface of plug 110 and interior casing surface 118 in resisting movement of plug 110 under the influence of external forces.

Opposed, internal flanges 123 and 125 extend into chamber 126 from internal casing wall 121 to present a clearance opening 124 therebetween. Flanges 123 and 125 may be separately formed as illustrated, or could, if desired, constitute an annular type flange similar to disc 22 above described in connection with the other embodiments of the invention. As illustrated, tapered portion 119 of casing 116 need not be annular in transverse cross section and may be defined by an external casing surface 127 of slightly elliptical cross section, other configurations for surface 127 obviously being frusto-conical or frusto polygonal, pyramidal. The elliptical configuration is illustrated as the preferred form of this embodiment, since such configuration is normally adapted to provide a tight fit in the outer portion of a human ear under circumstances of maximum comfort. As will be clear from the drawing, the transverse cross section of the tapered part of chamber 126 may also be other than annular and, in the preferred form illustrated, is slightly elliptical, it being observed that such configuration tends to enhance the resistance offered by tapered surface 121 to travel of plug 110 under the influence of external forces.

The operation of this form of the invention obviously involves application of the same principles above described with respect to the forms of the invention illustrated in Figs. 1 to 4 inclusive and will, therefore, be clear to those skilled in the art without further explanation.

It will be obvious to those skilled in the art that certain minor modifications or changes may be made in some of the details of construction of the improved hearing guard contemplated by this invention, without materially departing from the true spirit or intention of this invention. Accordingly, it is intended that this invention shall be deemed limited only by the scope of the appended claims.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. An ear protector comprising a tubular casing of resilient material having an elongated chamber therein, the transverse cross sectional area of the chamber being greater adjacent one end thereof than at a point spaced from said one end thereof; and an elongated, longitudinally perforated, filter plug slidably housed within the chamber and having a zone of transverse cross sectional area greater than the transverse cross sectional area of the chamber at said point, said plug having a major portion of its lateral surface in frictional engagement with the casing.

2. An ear protector comprising an elongated, tubular casing of resilient material having a side wall of annular, transverse cross section, an inturned, annular flange at one end of the casing, and a perforated disc at the opposite end of the casing, presenting an elongated chamber of circular, transverse cross section within the casing; ear engaging structure adjacent said opposite end of the casing adapted for holding the latter in place in the outer canal of the human ear; and an elongated, frusto-conical, filter plug of lesser length than the chamber, having a longitudinal bore therethrough and disposed within said chamber with the larger end of the plug nearest said one end of the casing, the diameter of the larger end of the plug and the diameter of the chamber adjacent said one end of the casing being substantially the same, the diameter of the chamber being inwardly tapered throughout a portion of its length adjacent said one end of the casing as the opposite end of the latter is approached at an angle at least as great as the angle of taper of the plug, whereby the plug is retarded in moving toward said opposite end of the casing by frictional engagement between the side wall of the casing and portions of the plug intermediate the ends of the latter, as well as by the inertia of the plug itself.

3. In the protector as set forth in claim 2, wherein the angles of taper of the chamber and the plug are equal.

4. In the protector as set forth in claim 2, wherein the chamber is tapered convexly of its length.

5. In the protector as set forth in claim 2, wherein the surface of the side wall defining the chamber is undulated longitudinally of the chamber.

6. In the protector as set forth in claim 2, wherein is provided an elongated tab element extending from said one end of the casing in a direction opposite said opposite end of the casing and substantially parallel to the longitudinal axis of the casing, said element having a knob on the free end thereof.

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UNITED STATES PATENTS

2,427,664 Dunbar et al. ---------- Sept. 23, 1947

EXHIBIT S

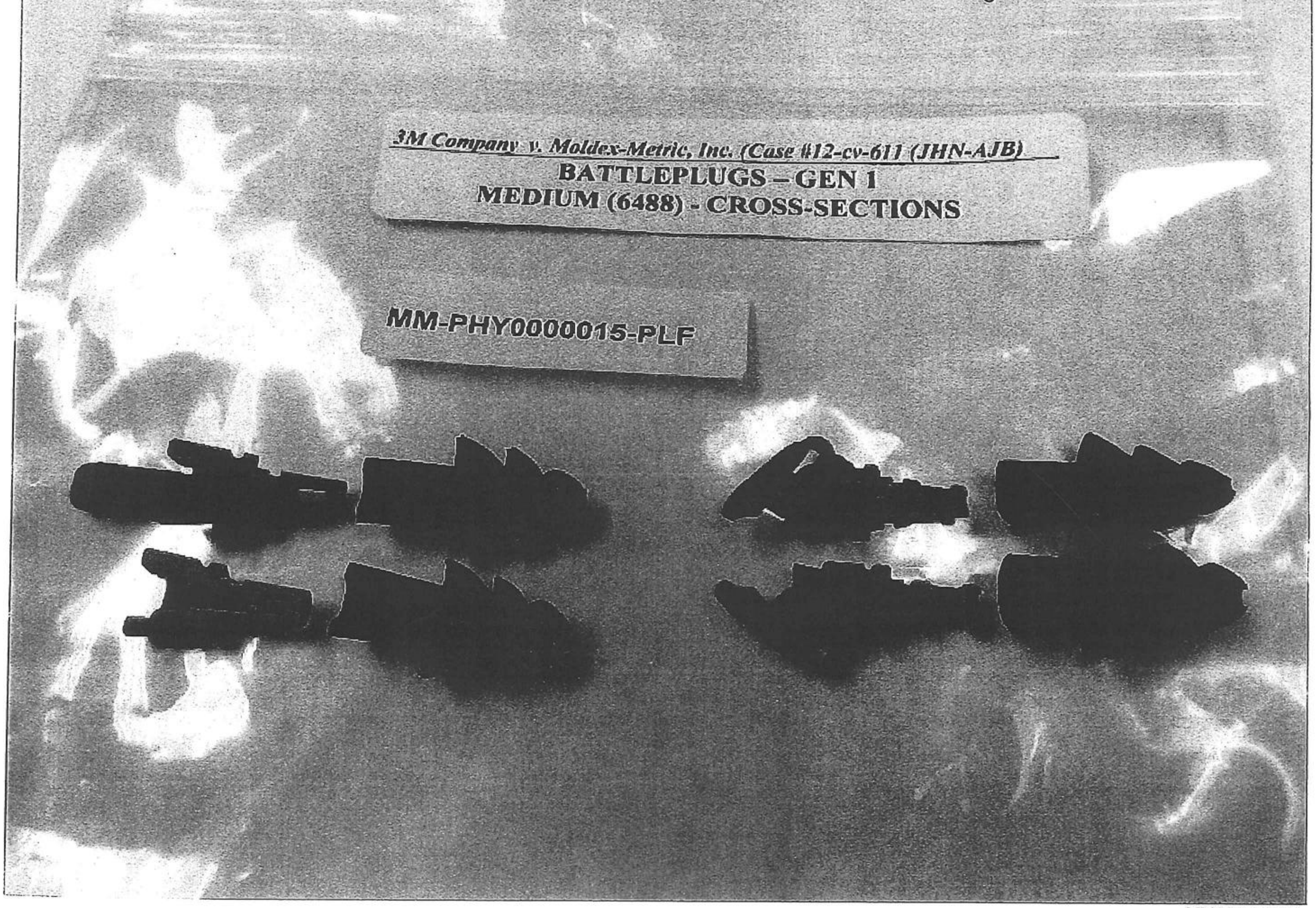
3M Company v. Moldex-Metric, Inc. (Case #12-cv-611 (JHN-AJB)
BATTLEPLUGS – GEN 1
MEDIUM (6488) - CROSS-SECTIONS
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EXHIBIT T

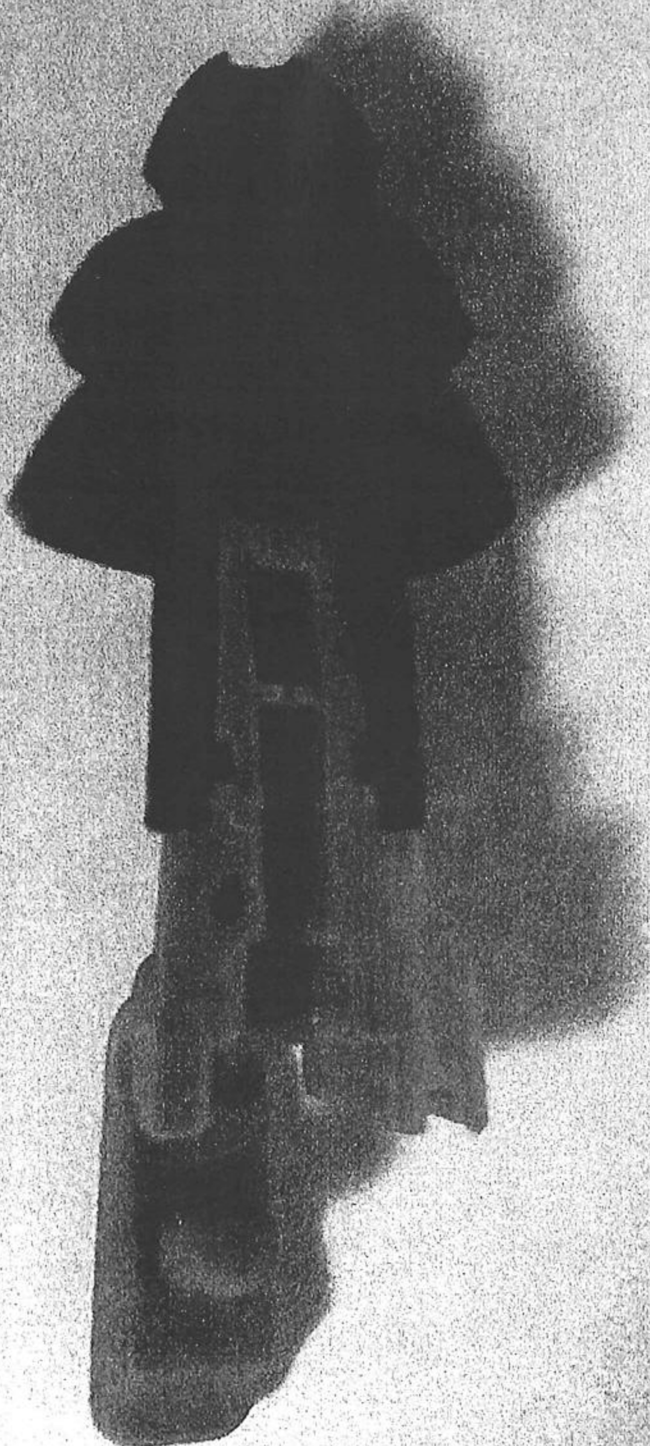

EXHIBIT U

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